A pilot study for assessing the potential plant community impacts of re-introducing grazing to Scotts Bluff National Monument: Results and implications for further investigation

South Bluff Unit, Scotts Bluff National Monument

Keller ranch adjacent to South Bluff Unit

Amy J. Symstad
USGS, Northern Prairie Wildlife Research Center, Black Hills Station
Mount Rushmore National Memorial
13000 Highway 244, Building 31, Suite 1
Keystone, SD 57751

FINAL REPORT
Natural Resources Preservation Program, Regional Small Park Allocation Fund
FISCAL YEAR: 2004
DATE: February 24, 2005

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

APPENDIX: Summary of data for all sample sites and all species.

ACKNOWLEDGMENTS: I heartily thank the staff of the Heartland Inventory and Monitoring Network and Prairie Cluster Prototype Monitoring Program, particularly Mike DeBacker and Alicia Sasseen, for their assistance in developing and completing this project. Jonathan Dingler provided additional field support and did all data entry, and Deb Buhl provided statistical assistance and review. Bob Manasek provided critical logistical support at the Monument, and Dan Licht and James Stubbendieck provided helpful comments on an earlier draft of this report. Finally, I sincerely thank Kevin Keller for access to his land.

Introduction

When a person thinks of the American Great Plains, images of wide, open grasslands stretching as far as the eye can see are sure to come to mind. That person will also often think of the huge herds of bison that once grazed on these plains, moving from one place to another in search of good forage. An image of a fire racing across the plains may also spring into thought. For thousands of years these processes – grazing and fire – were part of the ecosystems that comprise the Great Plains. European settlement drastically changed the Plains ecosystems, though, by replacing large migratory herds of bison – occasional grazers – with more continuous cattle grazing, and by suppressing fires. National Parks within the Great Plains seek to maintain and restore these processes, not only to provide visitors the experience of the Great Plains as they used to be, but also to preserve the biological diversity that they harbor. Prescribed burning programs have returned one of these vital processes to most prairie parks, but grazing by large herbivores is more difficult to implement, particularly in small parks. Currently, Scotts Bluff National Monument (NM) contains significant areas of native prairie but does not have any large grazers like the bison that helped form and maintain the mixed-grass prairie ecosystem.

Just as fire suppression has impacted many native ecosystems, this lack of grazing may also have significant effects on the prairie. Besides the obvious effect of grazing on the stature of vegetation, grazers impact plant community composition through their preferences for some species over others. For example, shorter grasses often increase in the presence of grazing because of reduction in competition from the taller grasses that grazers select (Bragg and Steuter 1996). In addition, large herbivores often increase grassland plant diversity (Olff and Ritchie 1998). For example, long-term research in the Flint Hills of Kansas suggests that frequent fires lead to decreases in plant species richness, but bison grazing offsets this diversity loss (Collins et al. 1998). These effects of grazers on prairie plant diversity stem from the heterogeneity that grazers introduce into an ecosystem at multiple scales (Truett et al. 2001). Trampling and removal of vegetation at the level of single hooves and plants can open microsites of bare soil, creating opportunities for recruitment of plant species that require open ground for establishment (Knapp et al. 1999). Trampling and wallowing (bison, but not cattle, do the latter) at the scale of whole animals or herds can create larger areas of bare ground where whole communities of early successional species, often broad-leaved forbs that comprise the largest fraction of plant diversity in the prairie, can exist. At the landscape scale, areas preferred by grazers because of topography, water availability, or previous grazing (which increases plant nutrient status and palatability) often host very different plant communities than areas which are infrequently or lightly grazed. This mosaic of plant communities often provides potential habitat for a wider variety of species, both plant and animal, than a homogenous landscape of the same size (Fuhlendorf and Engle 2001). Thus, the lack of large herbivore grazing in the native prairies at Scotts Bluff NM may limit the diversity of the plant communities within the park to levels lower than in pre-settlement times.

Also, if applied carefully, grazing may be used to control some invasive exotic plants. There is some evidence that uniformly heavy spring grazing may be a useful management tool for controlling *Bromus tectorum* and *B. japonicus*[1] (Daubenmire 1940, Whisenant and Uresk 1990, Young and Allen 1997), both of which are abundant and a major management concern at Scotts Bluff NM. However, the response of annual brome grasses to grazing varies widely among sites (Young and Allen 1997).

---

[1] Nomenclature follows that approved by the Integrated Taxonomic Information System (www.itis.usda.gov). Common names of all species mentioned in the text are listed in Appendix 1.

On the other hand, high-intensity grazing over long time periods may significantly reduce plant diversity (Fuhlendorf and Smeins 1997) and increase the diversity and abundance of undesirable, invasive species (DiTomaso 2000). Depending on the intensity of grazing occurring in the region surrounding Scotts Bluff NM, areas such as the Monument that are not grazed may provide some heterogeneity to the landscape as a whole, and may even serve as reservoirs for plant species that are negatively affected by grazing.

To summarize, there is concern that the lack of grazing, a keystone process of the Great Plains grasslands, at Scotts Bluff NM is having negative impacts on the prairie ecosystem. Consequently, it has been suggested that a grazing program should be considered for Scotts Bluff NM and other small prairie parks like it. Before any decisions regarding such a radical change in natural resources management can be made however, information on the potential effects of the decision is needed. This document reports on the results of a pilot project designed to begin addressing this information need.

Although grazing of any kind can affect many different components of an ecosystem, from the plant and animal communities to nutrient cycling, soil compaction, and water infiltration, this study focused on the structure and composition of the plant community within the dominant vegetation type at Scotts Bluff NM. By comparing this between the ungrazed Monument and an adjacent private cattle ranch, some preliminary conclusions about the potential impacts of introducing cattle grazing into Scotts Bluff NM can be drawn. More importantly, the results of this work are intended to help Monument natural resource and administrative staff to determine whether further study, including grazing experiments at the park, should be considered.

Methods

Study area

Scotts Bluff NM lies in the west-central portion of the Nebraska Panhandle on the southern bank of the North Platte River near the towns of Gering and Scottsbluff. The 3,003 acre park was established in 1919 to preserve and protect two large bluffs that rise from the surrounding prairie, the historical and cultural legacy attached to these bluffs, and the trails that passed between them. The natural vegetation of the area is mixed-short grass prairie on the plains, pine/juniper woodland on portions of the bluffs, and sparse to no vegetation in an area of badlands between Scotts Bluff and the North Platte River.

Public grazing was allowed on the property until the Monument’s establishment in December 1919, after which a three-year grazing permit was given to a local citizen. No other use by domestic livestock has occurred since then except for a war-time permit for a portion of the monument’s property in 1943-45 (Harris 1962). Wild large herbivores in the Monument consist of white-tailed deer, mule deer, and bighorn sheep. Grazing pressure on the grasslands has therefore been low for at least 58 years, since the deer feed primarily on woody vegetation and the grass-eating sheep are extremely rare. Prairie dogs do occur in the Monument, but they are not in the area sampled for this study.

The area sampled for this project is in the South Bluff management unit of the Monument (Figure 1). Approximately 65 ha in size, the only recorded fire at the site was a prescribed fire in March 1998. The vegetation in this area is dominated by *Hesperostipa comata-Bouteloua gracilis-Carex filifolia* mixed-grass prairie, but also contains *Symphoricarpos occidentalis* (western snowberry) Shrubland and Eroding Plains/Badlands sparse vegetation (Aerial

Information Systems 1998). The major soil type is Mitchell Silt Loam, and most of the area has rolling topography (slopes 3-20%).

The private ranch used for comparison in this study belongs to the Keller family. It lies on the southwest border of the Monument and the vegetation within it was mapped as part of the USGS-NPS Vegetation Mapping Program (Aerial Information Systems 1998). The area sampled is approximately 65 ha in size; it has not burned and is similar to the adjacent area in the Monument in soils, topography and vegetation. The area is currently grazed by cattle, with stocking rate and timing of stocking varying from year to year depending on climate and market conditions, a practice typical of operations in the region.

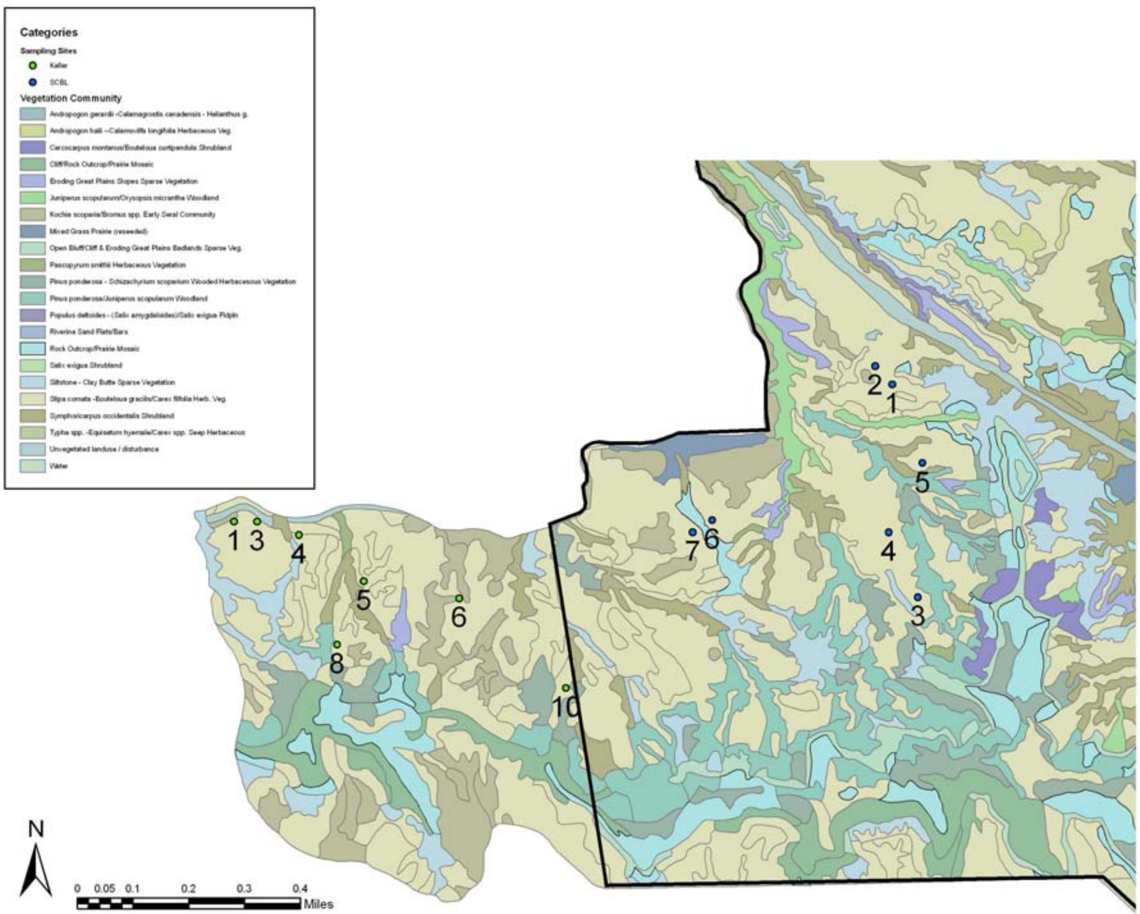

Figure 1. Vegetation associations and sampling locations in South Bluff management unit at Scotts Bluff National Monument (blue points) and the adjacent Keller ranch (green points). The heavy dark line indicates the Monument's boundary.

Vegetation sampling

Vegetation sampling was done on June 22-23, 2004 as part of the regular schedule of the NPS Heartland Inventory and Monitoring Network and Prairie Cluster Prototype Monitoring

Program (HTLN)[1]. It should be noted that this was in the midst of an extreme drought (Palmer long-term drought index < -4.00), with precipitation over the last year in the bottom tenth percentile of all previously recorded years (National Climate Data Center 2004b, a).

Seven permanent sites within the South Bluff management unit monitored by this program since 1997 were used for the samples within the Monument; seven additional, but temporary, sites were established in the adjacent Keller ranch in early June 2004. DeBacker et al. (DeBacker et al. 2004) describe the methods used by HTLN for collecting plant community data at Scotts Bluff NM. Following this protocol, sample sites were located following a stratified random approach using soil type and landscape position (upper slope, middle slope, and lower slope) to define strata within a management unit. Sample sites were allocated to each of these strata based on the proportion of the management unit in each category designated for each stratum. In the South Bluff management unit, this stratified-random approach yielded ten sampling sites within the management unit. One of these sites is no longer sampled by HTLN, and two others were not used in this study because they are on steep slopes and in vegetation not often used by cattle.

Because the HTLN sites that were appropriate for this study all fall in the *Hesperostipa comata-Bouteloua gracilis-Carex filifolia* Mixed-Grass Prairie vegetation association (as designated by the vegetation map produced for the park in 1998; Figure 1), sampling sites at the Keller ranch were also confined to this vegetation association. This was done to reduce differences in vegetation between the two study units simply due to the dominant species (by which vegetation association is characterized). Locations for seven sampling sites at the Keller ranch (Figure 1) were chosen randomly within the *Hesperostipa comata-Bouteloua gracilis-Carex filifolia* vegetation type and established at the beginning of the field season.

Each sample site was set up in the following manner. First, two parallel 50-m transects (their orientation randomly chosen) were placed 20 m apart and five 10 m^2 circular plots were located along each transect. Three plots, one each of three sizes (0.01 m^2, 0.1 m^2, and 1 m^2), were nested within each of the 10 m^2 plots. Species presence was recorded for each of the plots. Two additional 50-m transects were placed parallel to and between the two original transects at a random distance from one of the original transects. Along each of these additional transects, (1) plant basal cover or ground cover (soil, litter, rock, etc.) was recorded every half-meter following the modified step-point method (Owensby 1973), and (2) nested frequency plots (0.1 m^2 and 0.01 m^2), in which plant species presence is recorded, were located every 3 m. (See Figure 2.) Finally, a complete species list was compiled for the 1000 m^2 area encompassed within the outer transects of each sampling site. Table 1 summarizes this design, showing the number of each size of plot sampled at each site.

Table 1. Number of points and plots of each size at each sampling site.

Point or Plot Size (m^2)	Number at each Site
point	200
0.01	42
0.1	42
1	10
10	10
1000	1

[1] previously the Prairie Cluster Prototype Long Term Ecological Monitoring (LTEM) program

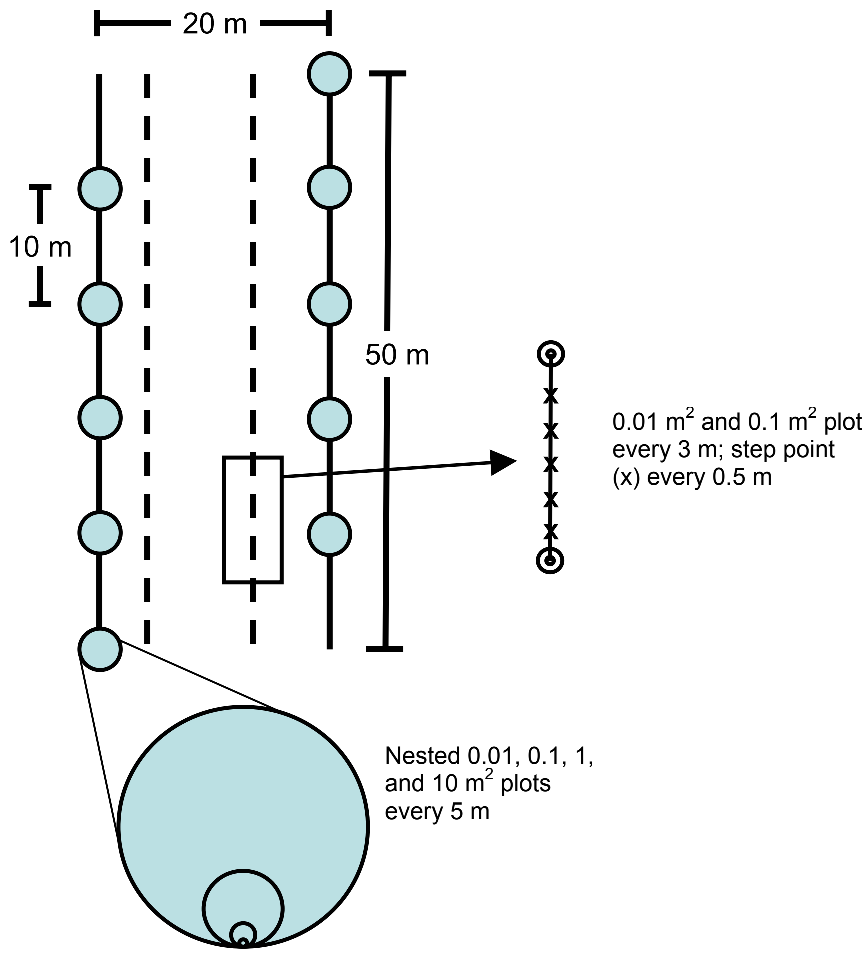

Figure 2. Layout of transects and plots at each sampling site.

Data Analysis

For all analyses, *Bromus japonicus* and *B. tectorum* were treated as one species (*Bromus* spp.) as were *Pascopyrum smithii* and *Elymus trachycaulus* (*Pascopyrum smithii-Elymus trachycaulus*) because of difficulties in distinguishing between the two species in each group in the field.

Two types of data result from the sampling methods described above – cover and frequency. Basal cover of plants, which is relatively insensitive to short-term grazing impacts and more indicative of the long-term effects of grazing, was measured with the modified step-point method. Total basal cover and basal cover of five individual species were calculated as the percentage of points along the step-point transects in which any of the individual species, respectively, was hit. Cover of bare soil and litter were similarly calculated from the step-point data. Because of the small area sampled with this method, only a small portion of the total diversity of a site is captured, making the method most useful for comparing the abundance of common species. T-tests were used to compare total or species basal cover and bare soil or litter cover between the Monument and Keller ranch properties.

Frequency in the plots was also used to compare the abundance of some individual species between the two properties using t-tests. The interpretation of frequency data is complicated by the relationship between the size of the plot used and frequency. Larger plots yield higher frequencies. An optimal plot size for determining differences in frequency is one which yields frequencies between 30 and 70% (Elzinga et al. 1998), and this optimal plot size will vary among species because of their differences in abundance. Frequency of dominant species is thus measured using smaller plots than frequency of rare species. The plot size used for comparing the abundance of individual species was determined by calculating the frequency of each species over all samples for each plot size, then choosing the plot size yielding a frequency closest to 50%. Only species with a frequency greater than 30% in a plot size <1000 m^2 were used, yielding seven species. T-tests were used to compare the frequency of these seven species between the two properties.

The information contained in these seven species is relatively small compared to what is contained in the complete plant community, however. Thus, the multi-response permutation procedure (MRPP) in PC-ORD (McCune and Mefford 1999) was used to test for differences in overall plant community composition between the two properties. This procedure is similar to a t-test in that it is used to test for differences between two groups of samples. However, whereas a t-test uses only one response variable, MRPP uses multiple response variables. In this case, those response variables were the frequencies of all species measured in the 10 m^2 plots.

Increased heterogeneity is one potential effect of grazing. As a simple, inverse measure of heterogeneity, Jaccard similarity coefficients[1] were calculated between all possible pairs of sites within a property with the EstimateS software (Colwell 2001). Species composition for an entire sample site (as recorded in the 1000 m^2 plot species list) was used for these calculations. A t-test was used to see if the mean coefficient differed between properties.

Finally, total and exotic (non-native) species richness and the proportion of species richness that is exotic were calculated for the three largest plot sizes and compared with t-tests between the two properties.

The pooled variance method was used to calculate t-values unless variances were shown to be unequal ($P < 0.05$) using the Folded F method, in which case the Satterthwaite method was used (SAS Institute Inc. 2001). Because the sample size was small (N = 7) and it is important in this study to avoid missing real differences between properties (which is more likely with low statistical power), no correction to *P*-values was made for multiple comparisons.

Results

A total of 62 species were encountered in the sampling sites, only seven of which were exotic (Appendix 1). Based on some measures, the grazed and ungrazed properties were not very different. Bare soil cover, total plant basal cover, and basal cover of four of the five target species did not differ significantly between the areas sampled in the South Bluff unit of Scotts Bluff NM and the Keller ranch (Table 2). In addition, the frequencies of seven of the eight species for which analyses could be done were not significantly different (Table 3). The proportion of species that were exotic was also similar between properties in all the scales in

[1] The Jaccard index measures the similarity in species present in two samples. It is calculated as $a/(a + b + c)$, where a = the number of species present in both samples, b = the number of species present in the first sample but not the second, and c = the number of species present in the second sample but not the first.

which it was measured, as were total and exotic species richness in the 1 m^2 and 10 m^2 plots (Table 4).

There were significant differences in other measures, however, particularly those involving more than just the most common species. The one common species that did show significant differences in abundance, both as basal cover and frequency, was *Bouteloua gracilis*. It was more abundant in the grazed property than in the ungrazed property. One other species, *Vulpia octoflora*, showed a tendency to be more abundant at the ranch than at the Monument (Table 3).

Also, litter cover was significantly higher in the South Bluff unit than at the Keller ranch (Table 2), and native and exotic species richness were both significantly higher in the ungrazed unit than in the grazed ranch in the 1000 m^2 plots (Table 4). Variability in plot species composition among sites within a property also differed significantly at this largest scale. The mean Jaccard coefficient for site pairs in the South Bluff unit was 0.47 (se = 0.02), which was significantly lower than that for the Keller ranch (mean = 0.54, se = 0.02; t = 2.09, P = 0.04). Finally, there were significant differences between the two properties in overall plant community composition as measured in the 10 m^2 plots (T = 0.072, P = 0.012).

Table 2. Soil and plant basal cover in the grazed Keller ranch and ungrazed South Bluff unit of Scotts Bluff NM. Values shown are cover means and standard errors (in parentheses), expressed as percent. The final column shows the *P* value for testing for differences in the variable between the two properties.

Variable	Keller ranch	South Bluff unit	*P*
Bare	41.6 (5.5)	30.7 (3.0)	0.11
Total plant	9.3 (1.7)	6.1 (1.5)	0.12
Litter	47.1 (6.2)	62.9 (2.9)	**0.04**
Bouteloua gracilis	2.9 (1.1)	0.0 (0.0)	**0.04**
Bromus spp.	0.4 (0.1)	0.7 (0.3)	0.31
Carex filifolia	5.1 (1.1)	3.4 (1.0)	0.27
Hesperostipa comata	0.6 (0.1)	1.4 (0.5)	0.14
Pascopyrum smithii-Elymus trachycaulus	0.2 (0.1)	0.5 (0.2)	0.26

Table 3. Frequency of seven species in the grazed Keller ranch and ungrazed South Bluff unit of Scotts Bluff NM and the plot size used for calculating frequency. Frequency values shown are means and standard errors (in parentheses), expressed as percent. The final column shows the *P* value for testing for differences in the species' frequency between the two properties.

Species	Plot Size (m^2)	Keller ranch frequency	South Bluff unit frequency	P
Bouteloua gracilis	1	81.4 (7.7)	8.6 (4.0)	**<0.0001**
Bromus spp.	1	42.9 (13.4)	57.1 (16.0)	0.51
Carex filifolia	0.01	62.2 (7.5)	59.2 (6.7)	0.77
Hesperostipa comata	0.1	19.0 (6.6)	26.5 (6.2)	0.53
Pascopyrum smithii-Elymus trachycaulus	0.1	49.0 (6.5)	50.0 (13.0)	0.95
Sphaeralcea coccinea	1	20.0 (6.2)	32.9 (6.8)	0.19
Vulpia octoflora	1	41.4 (8.6)	18.6 (7.4)	0.07

Table 4. Species richness and percentage of species richness that is exotic in three plot sizes in the grazed Keller ranch and ungrazed South Bluff unit of Scotts Bluff. Values are means and standard errors (in parentheses).

Variable	Keller	South Bluff unit	*P*
Total species richness			
1 m^2 plots	4.4 (0.2)	4.0 (0.2)	0.17
10 m^2 plots	6.1 (0.3)	6.5 (0.3)	0.39
1000 m^2 plots	15.1 (1.0)	26.1 (3.2)	**0.01**
Exotic species richness			
1 m^2 plots	0.4 (0.1)	0.6 (0.2)	0.43
10 m^2 plots	0.6 (0.1)	0.9 (0.2)	0.21
1000 m^2 plots	1.4 (0.2)	3.4 (0.5)	**0.008**
Percent of species richness that is exotic			
1 m^2 plots	10.4 (4.0)	14.8 (4.1)	0.46
10 m^2 plots	9.5 (2.5)	13.2 (2.8)	0.34
1000 m^2 plots	9.6 (1.4)	13.2 (2.8)	0.13

Discussion

Ideally, a study to investigate the potential effects of introducing grazing into Scotts Bluff NM would have used replicated experimental treatments to investigate the effects of various grazing regimes on a variety of plant communities over a time period covering a wide range of annual climatic conditions. In contrast, this pilot study used observational methods to compare the plant community composition of a single vegetation association (characterized by known dominant species) between just two properties (one grazed and one not) in a single growing season in the midst of an extreme drought. Consequently, no definitive conclusions can be drawn from this work alone. Thus, this discussion focuses on interpreting the results of the pilot study for the purpose of determining what other research and evaluation is necessary in deciding if *not* having grazing is detrimental to the park's ecosystem and whether to consider introducing large ungulates into small prairie parks.

Results from this work

The results of this study showed almost no difference in the abundance of the most common species between the grazed and ungrazed properties. This is not surprising for two reasons. First, sampling was limited to a vegetation association characterized by four of these species. Second, previous work in northern mixed-grass prairie has shown that climate, especially precipitation, is the primary driver of grassland vegetation composition, with grazing regime having a secondary effect within the climate context (reviewed in Biondini et al. 1998), or no effect at all depending on the grazing intensity (Biondini et al. 1998, Heitschmidt et al. 1999). Thus, given that this study took place at a time when climate effects would be expected to be extremely strong, the fact that any differences between the two properties were found is notable. The one species that did differ in abundance between the properties was *Bouteloua gracilis*, a short-statured, warm-season grass. This species and the native annual grass *Vulpia octoflora*, which tended to be more frequent in the grazed property, have been shown in previous work to increase in community importance when vegetation is grazed (Smith 1940, Herbel and Anderson 1959), so these results are to be expected. It is somewhat curious, however, that the abundances of other major species in the vegetation association – *Nassella viridula, Carex* *filifolia,* and *Pascopyrum smithii-Elymus trachycaulus* – were not correspondingly lower in the grazed property. It is also noteworthy that the abundance of the major invasive species of concern – annual brome grasses – did not differ between properties, even though the Kellers have specifically targeted grazing practices to reduce these species in the past (K. Keller, pers. comm.). The measure of abundance used in this study (frequency) may not be sensitive enough to capture subtle changes in the relative importance of species in a community. In addition, the small sample size makes detecting differences difficult.

The greater cover of litter in the ungrazed Monument is also consistent with expectations and other research (McNaughton et al. 1988, Biondini et al. 1998), since grazing removes plant biomass from the community. The lower litter cover at the ranch was not matched by a similar increase in bare soil cover, however, suggesting that the grazed property did not provide greater opportunities for recruitment of various species. This and many other factors may account for the lower site-scale species richness in the grazed ranch property than the ungrazed Monument. Although it is tempting to surmise that the long history of grazing on the private property has eliminated grazing-sensitive species, the lack of control in this study for other factors makes this only one of many possible explanations.

Since the major invasive species at this site, *Bromus* spp., were not considerably more abundant in the grazed property, and exotic species richness was actually higher in Monument samples than in ranch samples, competition from invasive species is probably not the explanation. An interaction between drought and grazing may be at least partly responsible. In an experimental drought-grazing study in Montana in a grassland of similar composition to those in this study, forbs were more abundant in grazed areas only when water availability was sufficient (Hild et al. 2001). Thus, the combination of drought and grazing may have had adverse impacts on the species richness of forbs (which comprise the majority of species richness in grasslands) in the Keller property. Greater heterogeneity among sample sites at the Monument may also have played a role, as indicated by the greater difference in species composition between sites within this property than within the ranch. This greater heterogeneity may be simply a mathematical consequence of the overall greater diversity of species in the area sampled within the Monument (overall, 23 more species were encountered in samples at the Monument than at the ranch), or it may result from greater heterogeneity in underlying factors that affect plant species diversity and composition, such as soils and topography. Although these last two factors were somewhat controlled for in this study, detailed information was not collected, so some variability may have existed. For example, Site 4 at the Monument was unique in that it encompassed part of a "blowout"-like feature (area of reduced vegetation due to wind erosion). This site had the greatest 1000 m^2-species richness (37) as well as the greatest number of unique species (8 species at this site occurred in no other site in the South Bluff unit). This site and Site 6, which had six unique species, accounted for half of the species occurring at the Monument but not encountered in the ranch, suggesting that these two sites may be responsible for the significant difference in overall species composition between the two properties.

Whatever the underlying cause of the greater plant species richness in the ungrazed South Bluff unit compared to the ranch property, it is probably the most important result to come out of this study. Overall, 29 of 57 species at the Monument were unique to Monument samples; three of these (10%) were exotic (*Lactuca serriola*, *Poa pratensis*, and *Sisymbrium altissimum*). Information on sensitivity to grazing could be found (Sedivec and Barker 1998, Johnson and Larson 1999, Larson and Johnson 1999) for 22 of the native species unique to the Monument;

there was no strong tendency for these to be grazing sensitive (twelve are considered grazing-sensitive and ten often increase in abundance in response to grazing). In contrast, only five of the 33 species encountered in the Keller ranch sample sites were unique to that property; one of these (20%) was exotic (*Agropyron cristatum*). All three of the native species unique to this property for which information could be found tend to respond positively to grazing. Thus, although the greater diversity of species in the Monument samples suggests that the Monument may be a refuge for grazing-sensitive species, the evidence from the composition of those species is equivocal. In addition, this study did not include a complete inventory of species in either of the properties involved, so it is very possible that some of the species identified as occurring only in the Monument property do actually occur in the grazed Keller ranch. Clearly much more extensive investigation is necessary to understand this result.

Before moving on to discussing the implications of these results for further investigation, two things should be noted. First, there are many types of grazing regimes and this study compared the vegetation in only two. A grazing regime is defined not only by the number of animals per acre, but also by when the grazing occurs (which season(s) or parts of seasons, whether it is continuous or rotational, the length of rest periods, etc.), whether the animals have free range of a large area or are confined to small areas, and which animals are used (horses, cattle, bison, sheep, etc.). All of these factors influence “grazing effects.” Indeed, given the right combination of these factors, the plant species diversity within the Monument could probably be increased beyond what it is now. Second, this study looked only at differences in vegetation composition between the grazed and ungrazed properties. One of the most striking and obvious effects of grazing on vegetation is of course the difference in structure (see photos on report cover). This is important not only for how it looks to people, but also for how it affects other species. Grassland-nesting birds and prairie dogs are just two examples of species that choose their homes based largely on vegetation height. In addition, as noted in the Introduction, grazing can significantly affect other ecosystem properties, from nutrient cycling to stream-bank structure.

What this means for the next step

Obviously there are many issues that must be addressed when considering a change in natural resource management as sweeping as introducing large grazers. These include logistical issues (e.g., water availability, fencing, personnel for handling animals and/or contracts), natural resource issues (e.g., impacts on vegetation, wildlife including prairie dogs, soil erosion, and water quality), issues involving both logistics and natural resources (e.g., grazing regime, location of grazing), policy issues (e.g., Could domestic livestock be used or are native species the only option? Is grazing consistent with the establishing legislation for the park? How does a park choose between the need to contribute to the conservation of regional biological diversity [e.g., a non-grazed site] with a need to conserve natural conditions and processes [e.g.,. grazing]?), and visitor issues (e.g., safety, acceptance of different species, impact on visiting experience). This pilot study was designed to address a small part of one of these issues – the potential impacts on plant community composition.

If the possibility of introducing grazers is going to be pursued, this study yields two important results useful for directing further investigation. The first is the suggestion that the Monument may serve as a refuge for grazing-sensitive plants. To rigorously investigate this, a thorough plant inventory, including quantitative data collection on species abundance in areas managed with various grazing regimes, of the Scotts Bluff region would be necessary. This is unlikely to happen. However, a decent substitute for it was completed in 1995-96 when a rare plant survey (Rolfsmeier 1996) and a grassland plant community description (Hildebrand 1996) of the Wildcat Hills and Scotts Bluff National Monument were done. Since one of the goals of the latter work was to characterize the plant community composition of high quality prairie vegetation for the Monument's prairie restoration efforts, many of the best remaining examples of mixed grass prairie in the region were sampled. Although not stated in either of these reports, at least one of the investigators apparently expressed to Monument natural resources staff that the Monument contained much of the best quality mixed-grass prairie of those areas sampled (R. Manasek, personal communication). In addition, ten species on the Nebraska state rare species list were found at the Monument; seven of these were found only there out of the twelve sites visited. Little information exists as to the grazing sensitivity of these ten species, however, and six of them are restricted to rock outcrops and badlands habitat unlikely to be visited by livestock if grazing were introduced into the Monument. Whether this issue (the Monument serving as a refuge) is pursued depends on how important it is compared to the many other factors to be weighed when making a decision as to whether the lack of an ecosystem process indigenous to the ecosystem within the Monument (grazing) is a problem that should be remedied.

The second important result of this study is that, although the design and small sample size limit inferences that can be made from the results of this study alone, the data collected provide the information needed to determine adequate sample sizes in future research. As mentioned above, the most rigorous method for determining grazing effects on vegetation at the Monument would be to monitor changes in vegetation within experimental trials of one or more grazing regimes plus an ungrazed control. Unless sampling is adequate in such trials, however, the results from such experimentation would lack statistical power just as in this pilot study. For example, one of the parameters that probably would be measured is the abundance of invasive annual brome grasses. Assuming that the same sampling method is used and that the variance of brome frequency calculated from this study's data is similar in other years and situations, it would take 37 sample sites in each grazing regime to be 70% confident that there was a difference of 20% in the frequency of these species between the two grazing regimes, assuming that a 10% chance of concluding that this difference exists when it really does not is acceptable. Table 5 shows the sample sizes needed for some other combinations of statistical power, false-difference error rate, and the difference in frequency that is necessary to detect. The sample sizes shown in the table suggest that perhaps the methods of measuring species abundance should be modified.

Table 5. Sample size in each grazing regime necessary to detect the given difference in annual brome grass frequency for various levels of α (false-difference error rate = chance of concluding there is a difference when there really is not) and desired statistical power (certainty of not missing a difference when it really exists). Values are based on a standard deviation of 39 for annual brome frequency.

Desired Power	*Detectable Difference = 10*		*Detectable Difference = 20*		*Detectable Difference = 30*	
	α = .05	α = .10	α = .05	α = .10	α = .05	α = .10
.70	189	144	48	37	22	17
.75	213	165	54	42	25	19
.80	240	189	61	48	28	22
.85	275	220	70	56	32	26
.90	321	262	81	66	37	30
.95	397	330	100	84	45	38

Finally, in this study, the ungrazed property had burned once, six years prior to the study, whereas the grazed property had no recent history of fire. Because the fire was so long ago, it is unlikely to have affected the outcome of this study. However, fire must be considered when weighing various factors in the decision of whether to re-introduce grazing into a park for a couple of reasons. First, because of the many logistical and political problems involved with grazing in any park, but particularly those like Scotts Bluff NM (small and/or adjacent to urban areas), prescribed fire has been suggested as a potential replacement for grazing. Fire is itself a process indigenous to this ecosystem, and some of its effects on vegetation are similar to those of grazing. A complete review of the similarities and differences of fire and grazing effects in northern mixed-grass prairie is beyond the scope of this report, but Table 6 provides some information for evaluating the use of fire as a replacement for grazing. Second, fire and grazing are not management actions that can be done independently. Grazers often preferentially graze unburned areas. Conversely, a fire often will not carry through grazed vegetation. Designing a grazing and fire regime that would meet management goals would need to account for these and other interactions between the two ecosystem processes.

Table 6. Brief comparison of effects of fire and grazing in northern mixed-grass prairie.

Ecosystem Property or Process	Fire Effect	Grazing Effect
vegetation composition	some species more affected than others depending on season of burn and woodiness	some species more affected than others depending on palatability and response to defoliation
vegetation structure	reduces height immediately and often for first year after burn	reduces height
vegetation heterogeneity	depends on regime and execution[1] of burns	depends on regime – often increases
standing biomass	decreases dead; may increase live, particularly in years not immediately after burn	decreases
litter load	decreases	decreases
bare ground	increases	generally increases
soil erosion	generally no effect	can increase
soil compaction	no effect	increases
nitrogen cycling	can stimulate, but some nitrogen lost to atmosphere instead of returning to soil	can stimulate; effects can be more patchy than from fire (urine and feces deposition)
wildlife	some direct mortality; indirect effects through vegetation	potential competition for forage; indirect effects through vegetation

[1] heading, flanking, backing fire; environmental conditions (fuel moisture, wind speed, temperature) during burn; etc.

Summary and Recommendations

There is concern that the lack of grazing, a keystone process of the Great Plains grasslands, at Scotts Bluff National Monument is having negative impacts on the prairie ecosystem. Consequently, it has been suggested that a grazing program should be considered for Scotts Bluff NM and other small prairie parks like it. Before any decisions regarding such a radical change in natural resources management can be made, information on the potential effects of the decision is needed. This document reports on the results of a single-season, observational pilot study that looked at one component of the ecosystem expected to be affected by grazing – the plant community in the most common vegetation association at the Monument.

For a variety of reasons, the similarities and differences in plant community composition and diversity between the two properties compared in this study (ungrazed South Bluff unit of the Monument and the adjacent Keller ranch) are not necessarily indicative of changes that would occur if grazing were re-introduced to the Monument. However, some definite conclusions and recommendations can be drawn from the results of this study as well as from copious amounts of literature on the topic (discussed above):

1. There is no evidence that the current management practice of *not* having grazing, when compared to the grazing regime in the adjacent ranch, is detrimental to the vegetation association studied. Species richness was higher in the ungrazed Monument, and the abundance of invasive annual brome grasses apparently was not different between the two properties.
2. If grazing were re-introduced, plant community composition would almost definitely change. Some species, such as the short-statured warm-season grass *Bouteloua gracilis*, would likely increase in importance relative to other species. Grazing-sensitive species would likely decrease in abundance.
3. Changes would depend on the grazing regime implemented.
4. Further research is needed to determine the extent to which the Monument serves as a refuge for grazing-sensitive species in the region if this is deemed an important role of the Monument.
5. If grazing were implemented, thorough monitoring, using more samples and/or more statistically powerful sampling methods than those used in this study, would be necessary to determine whether the management practice is having the desired effect.

Literature Cited

Aerial Information Systems. 1998. Photo Interpretation Report, USGS-NPS Vegetation Mapping Program, Scotts Bluff National Monument. Aerial Information Systems, Redlands, CA.

Biondini, M. E., B. D. Patton, and P. E. Nyren. 1998. Grazing intensity and ecosystem processes in a northern mixed-grass prairie, USA. Ecological Applications **8**:469-479.

Bragg, T. B., and A. A. Steuter. 1996. Prairie ecology -- the mixed prairie. Pages 53-65 *in* F. B. Samson and F. L. Knopf, editors. Prairie conservation: preserving North America's most endangered ecosystem. Island Press, Washington, DC.

Collins, S. L., A. K. Knapp, J. M. Briggs, J. M. Blair, and E. M. Steinauer. 1998. Modulation of diversity by grazing and mowing in native tallgrass prairie. Science **280**:745-747.

Colwell, R. K. 2001. EstimateS: Statistical estimation of species richness and shared species from samples, Version 6.0b1.

Daubenmire, R. F. 1940. Plant succession due to overgrazing in the *Agropyron* bunchgrass prairie of southeastern Washington. Ecology **21**:55-64.

DeBacker, M. D., A. N. Sasseen, C. Becker, G. A. Rowell, L. P. Thomas, J. R. Boetsch, and G. D. Willson. 2004. Vegetation community monitoring protocol for the Heartland I&M Network and Prairie Cluster Prototype Monitoring Program. National Park Service, Heartland Inventory and Monitoring Network and Prairie Cluster Prototype Monitoring Program, Republic, Missouri.

DiTomaso, J. M. 2000. Invasive weeds in rangelands: Species, impacts, and management. Weed Science **48**:255-265.

Elzinga, C. L., D. W. Salzer, and J. W. Willoughby. 1998. Measuring and monitoring plant populations. Technical Reference 1730-1, Bureau of Land Management, Denver, CO.

Fuhlendorf, S. D., and D. M. Engle. 2001. Restoring heterogeneity on rangelands: Ecosystem management based on evolutionary grazing patterns. BioScience **51**:625-632.

Fuhlendorf, S. D., and F. E. Smeins. 1997. Long-term vegetation dynamics mediated by herbivores, weather and fire in a Juniperus-Quercus savanna. Journal of Vegetation Science **8**:819-828.

Harris, E. R. 1962. History of Scotts Bluff National Monument. Oregon Trail Museum Association, Gering, NE.

Heitschmidt, R. K., M. R. Haferkamp, M. G. Karl, and A. L. Hild. 1999. Drought and grazing I: Effects on quantity of forage produced. Journal of Range Management **52**:440-446.

Herbel, C. H., and K. L. Anderson. 1959. Response of true prairie vegetation on major Flint Hills range sites to grazing treatment. Ecological Monographs **29**:171-186.

Hild, A. L., M. G. Karl, M. R. Haferkamp, and R. K. Heitschmidt. 2001. Drought and grazing III: Root dynamics and germinable seed bank. Journal of Range Management **54**:292-298.

Hildebrand, T. 1996. A description of the grassland communities of the Wildcat Hills region of northwestern Nebraska including Scotts Bluff National Monument. Hildebrand Contracting, Sturgis, SD.

Johnson, J. R., and G. E. Larson. 1999. Grassland plants of South Dakota and the Northern Great Plains. South Dakota State University, Brookings, South Dakota.

Knapp, A. K., J. M. Blair, J. M. Briggs, S. L. Collins, D. C. Hartnett, L. C. Johnson, and E. G. Towne. 1999. The keystone role of bison in North American tallgrass prairie. BioScience **49**:39-50.

Larson, G. E., and J. R. Johnson. 1999. Plants of the Black Hills and Bear Lodge Mountains. South Dakota State University, Brookings, South Dakota.

McCune, B., and M. J. Mefford. 1999. PC-ORD. Multivariate Analysis of Ecological Data, Version 4. MJM Software Design, Gleneden Beach, Oregon.

McNaughton, S. J., R. W. Ruess, and S. W. Seagle. 1988. Large mammals and process dynamics in African ecosystems. BioScience **38**:794-800.

National Climate Data Center. 2004a. Nebraska Climate Overview - May 2004. URL http://www.ncdc.noaa.gov/oa/climate/research/2004/may/st025dv00pcp200405.html

National Climate Data Center. 2004b. Regional Drought Overview - June 2004. URL http://www.ncdc.noaa.gov/oa/climate/research/2004/jun/drought-regional-overview.html

Olff, H., and M. E. Ritchie. 1998. Effects of herbivores on grassland plant diversity. Trends in Ecology & Evolution **13**:261-265.

Owensby, C. E. 1973. Modified step-point system for botanical composition and basal cover estimates. Journal of Range Management **26**:302-303.

Rolfsmeier, S. B. 1996. Rare plant survey of the Wildcat Hills region of northwestern Nebraska. Milford, NE.

SAS Institute Inc. 2001. The SAS system for Windows, Version 8.02, Cary, NC.

Sedivec, K. K., and W. T. Barker. 1998. Selected North Dakota and Minnesota range plants [web page edition of publication]. URL http://www.ext.nodak.edu/extpubs/ansci/range/eb69-1.htm

Smith, C. C. 1940. The effect of overgrazing and erosion upon the biota of the mixed-grass prairie of Oklahoma. Ecology **21**:381-397.

Truett, J. C., M. Phillips, K. Kunkel, and R. Miller. 2001. Managing bison to restore biodiversity. Great Plains Research **11**:123-144.

Whisenant, S. G., and D. W. Uresk. 1990. Spring burning Japanese brome in a western wheatgrass community. Journal of Range Management **43**:205-208.

Young, J. A., and F. L. Allen. 1997. Cheatgrass and range science: 1930-1950. Journal of Range Management **50**:530-535.

Appendix 1.

The table on the following pages shows the basal cover ("Point") or frequency in each plot size (m^2) of all species encountered in samples at Scotts Bluff National Monument's South Bluff management unit and the privately owned Keller ranch property immediately adjacent to it. Cover and frequency values are expressed as percentages and were calculated for the property as a whole, which is equivalent to the mean over the seven samples in each property. On some rare occasions, the frequency in 0.1 m^2 plots is greater than that in 1 or 10 m^2 plots. This occurs when a species was encountered in the plots along the modified step-point transects but not in the plots along the standard transects. Species whose names are in **bold** are those that occurred only in samples at the Monument; species whose names are underlined are those that occurred only in samples at the Keller ranch.

Species	Common Name	Origin	Scotts Bluff NM South Bluff Unit						Keller Ranch					
			Point	0.01	0.1	1	10	1000	Point	0.01	0.1	1	10	1000
Achnatherum hymenoides	Indian ricegrass	native	0.0	0.0	0.0	0.0	0.0	14	0.0	0.0	0.0	0.0	0.0	0
Agropyron cristatum	crested wheatgrass	exotic	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	14
Ambrosia psilostachya	western ragweed	native	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	1.4	14
Artemisia frigida	fringed sagewort	native	0.0	0.0	0.0	0.0	0.0	14	0.0	0.0	0.0	0.0	2.9	29
Astragalus laxmannii	standing milkvetch	native	0.0	0.0	0.0	0.0	0.0	29	0.0	0.0	0.0	0.0	0.0	0
Astragalus gracilis	slender milkvetch	native	0.0	0.0	0.3	2.9	5.7	43	0.0	0.0	0.0	0.0	0.0	0
Bouteloua curtipendula	side-oats grama	native	0.0	1.0	1.4	4.3	8.6	57	0.0	0.0	0.3	0.0	0.0	14
Bouteloua gracilis	blue grama	native	2.9	0.7	5.8	8.6	34.3	100	0.0	23.5	51.4	81.4	90.0	100
Brickellia eupatoriodes	false boneset	native	0.0	0.0	0.0	0.0	0.0	14	0.0	0.0	0.0	0.0	0.0	0
Bromus spp.	Japanese brome, cheat-grass (annual bromes)	exotic	0.4	39.5	48.6	57.1	67.1	100	0.7	28.2	34.0	42.9	58.6	100
Calamovilfa longifolia	prairie sandreed	native	0.0	0.0	0.0	0.0	0.0	14	0.0	0.0	0.0	0.0	0.0	0
Calylophus serrulatus	yellow evening primrose	native	0.0	0.0	0.0	0.0	0.0	14	0.0	0.0	0.0	0.0	0.0	0
Carex filifolia	threadleaf sedge	native	5.1	59.2	80.3	87.1	97.1	100	3.4	62.2	79.3	88.6	95.7	100
***Carex* spp.**	sedge species	native	0.0	0.0	0.3	1.4	1.4	29	0.0	0.0	0.0	0.0	0.0	0
Chenopodium pratericola	desert goosefoot	native	0.0	0.0	0.0	4.3	11.4	86	0.0	0.0	0.0	0.0	0.0	0
Cirsium flodmanii	Flodman's thistle	native	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	29
Cirsium cf. *undulatum*	wavyleaf thistle	native	0.0	0.0	0.0	0.0	0.0	14	0.0	0.0	0.0	0.0	1.4	14
Erysimum capitatum	western wallflower	native	0.0	0.0	0.0	0.0	0.0	14	0.0	0.0	0.0	0.0	0.0	0
Escobaria sp.	pincushion cactus	native	0.0	0.0	0.0	0.0	1.4	29	0.0	0.0	0.0	0.0	0.0	29
Gaura mollis	scarlet gaura	native	0.0	0.0	0.3	0.0	14.3	100	0.0	0.0	0.0	0.0	1.4	14
Gutierrezia sarothrae	snakeweed	native	0.0	0.0	0.0	0.0	2.9	57	0.0	0.3	0.7	2.9	8.6	71
annual *Helianthus* sp.	annual sunflower	native	0.0	0.0	0.0	0.0	1.4	43	0.0	0.0	0.0	0.0	0.0	0
Hesperostipa comata	needle-and-thread	native	0.6	26.5	62.6	90.0	98.6	100	1.4	19.0	53.4	88.6	95.7	100
Koeleria macrantha	June grass	native	0.0	0.3	0.3	1.4	2.9	29	0.0	0.0	0.0	0.0	0.0	0
Krascheninnikovia lanata	winterfat	native	0.0	0.0	0.3	0.0	1.4	71	0.1	0.0	0.0	0.0	0.0	29
Lactuca serriola	prickly lettuce	exotic	0.0	0.0	0.0	0.0	0.0	14	0.0	0.0	0.0	0.0	0.0	0
Lappula occidentalis	western sticktight	native	0.0	0.3	0.3	1.4	1.4	29	0.0	0.0	0.0	0.0	0.0	0
Lathyrus polymorphus	manystem peavine	native	0.0	0.0	0.7	2.9	5.7	43	0.0	0.0	0.0	0.0	0.0	0
Liatris punctata	dotted blazing star	native	0.0	0.0	0.0	0.0	1.4	29	0.0	0.0	0.3	0.0	0.0	14
Lithospermum incisum	narrowleaf gromwell	native	0.0	0.0	0.0	0.0	1.4	29	0.0	0.0	0.0	0.0	0.0	0
Lygodesmia juncea	skeleton weed	native	0.0	0.0	1.4	2.9	27.1	100	0.0	0.0	3.1	7.1	22.9	71
Machaeranthera pinnatifida	spiny goldenweed	native	0.0	0.0	0.0	0.0	4.3	43	0.0	0.0	0.0	0.0	2.9	57
Muhlenbergia cuspidata	plains muhly	native	0.0	0.0	0.3	0.0	1.4	14	0.0	0.0	0.0	0.0	0.0	0

			Scotts Bluff NM South Bluff Unit						Keller Ranch					
Species	**Common Name**	**Origin**	**Point**	**0.01**	**0.1**	**1**	**10**	**1000**	**Point**	**0.01**	**0.1**	**1**	**10**	**1000**
Nassella viridula	green needlegrass	native	0.0	0.7	1.0	0.0	1.4	14	0.0	0.0	0.0	0.0	0.0	0
Opuntia fragilis	fragile prickly pear	native	0.0	0.0	0.0	0.0	1.4	14	0.0	0.0	0.0	0.0	1.4	14
Opuntia macrorhiza	bigroot prickly pear	native	0.0	0.0	0.3	0.0	10.0	100	0.0	0.0	0.3	4.3	14.3	100
Opuntia polyacantha	plains prickly pear	native	0.1	0.0	0.3	1.4	10.0	57	0.0	0.0	0.3	5.7	28.6	100
Pascopyrum smithii-Elymus trachycaulus	western wheatgrass-slender wheatgrass	native	0.2	21.4	50.0	67.1	77.1	100	0.1	22.8	49.0	61.4	74.3	100
Pediomelum argophyllum	silverleaf scurfpea	native	0.0	0.0	0.0	0.0	4.3	29	0.0	0.0	0.0	0.0	0.0	0
Penstemon albidus	white penstemon	native	0.0	0.0	0.7	0.0	0.0	29	0.0	0.0	0.0	0.0	0.0	0
Phlox andicola	prairie phlox	native	0.0	0.0	0.0	0.0	2.9	14	0.0	0.0	0.0	0.0	0.0	0
Phlox hoodii	spiny phlox	native	0.0	0.3	0.7	1.4	1.4	71	0.0	0.0	0.0	0.0	0.0	0
Physalis cf. *heterophylla*	clammy ground-cherry	native	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	0.3	0.0	0.0	29
Physalis cf. *hispida*	ground-cherry	native	0.0	0.0	0.0	0.0	0.0	14	0.0	0.0	0.0	0.0	0.0	14
Pinus ponderosa	ponderosa pine	native	0.0	0.0	0.0	0.0	0.0	14	0.0	0.0	0.0	0.0	0.0	0
Poa pratensis	Kentucky bluegrass	exotic	0.0	0.0	0.0	0.0	0.0	14	0.0	0.0	0.0	0.0	0.0	0
Psoralidium tenuiflorum	slimflower scurfpea	native	0.0	0.0	0.0	1.4	2.9	57	0.0	0.0	0.0	0.0	0.0	14
Rhus trilobata	skunkbush sumac	native	0.0	0.0	0.3	1.4	4.3	57	0.0	0.0	0.0	0.0	0.0	14
Rosa woodsii	Woods' rose	native	0.0	0.0	0.0	0.0	1.4	14	0.0	0.0	0.0	0.0	0.0	0
Salsola sp.	Russian thistle	exotic	0.0	0.0	0.3	1.4	10.0	86	0.0	0.0	0.0	0.0	0.0	14
Schizachyrium scoparium	little bluestem	native	0.0	0.0	0.3	2.9	2.9	14	0.0	0.0	0.0	0.0	0.0	0
Sisymbrium altissimum	tumbleweed mustard	exotic	0.0	0.3	0.3	1.4	5.7	71	0.0	0.0	0.0	0.0	0.0	0
Solidago missouriensis	Missouri goldenrod	native	0.0	0.0	0.0	2.9	4.3	57	0.0	0.0	0.0	0.0	1.4	14
Sphaeralcea coccinea	scarlet globemallow	native	0.0	1.7	9.2	32.9	65.7	100	0.0	1.4	9.2	20.0	55.7	100
Sporobolus cryptandrus	sand dropseed	native	0.0	0.0	0.3	1.4	2.9	29	0.0	0.0	0.3	0.0	2.9	43
Symphyotrichum ericoides	heath aster	native	0.0	0.0	0.3	0.0	0.0	14	0.0	0.0	0.0	0.0	0.0	0
Tragopogon dubius	goatsbeard, salsify	exotic	0.0	0.0	0.0	0.0	2.9	57	0.0	0.0	0.0	0.0	0.0	14
Verbena bracteata	prostrate vervain	native	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	1.4	14
Vicia americana	American vetch	native	0.0	0.0	0.3	1.4	2.9	29	0.0	0.0	0.0	0.0	0.0	0
Viola nuttallii	Nuttall's violet	native	0.0	0.0	0.0	0.0	1.4	14	0.0	0.0	0.0	0.0	0.0	0
Vulpia octoflora	sixweeks fescue	native	0.1	3.1	10.2	18.6	32.9	100	0.0	6.8	19.4	41.4	48.6	86
Yucca glauca	yucca, soapweed	native	0.0	0.0	0.3	0.0	11.4	71	0.0	0.0	0.0	0.0	1.4	43